In-Space Welding
Repair Working Group

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In-Space Fabrication and Repair Research Workshop
July 9, 2003

OUTLINE

- U.S. and Russian Background
- Existing Capabilities
- Current State of the Art
- Objectives of ISWE
- Design Drivers
- Technology Development Needs

U.S. Space Welding Background

- Skylab M512 Electron Beam welding experiment, 1973
- Pathfinder In-Space Assembly and Construction program, Code R, 1989
- In-Space Technology Experiments Program Technical monitors, Code R, 1989
- Space Act Agreement with McDonnell Douglas, 1993
- Fourth Call for Flight Demonstration Code D, awarded International Space Welding Experiment (ISWE) selected as a Flight Demonstration Project in 1994 for flight on STS-87 in 1997

Russian Space Welding Background

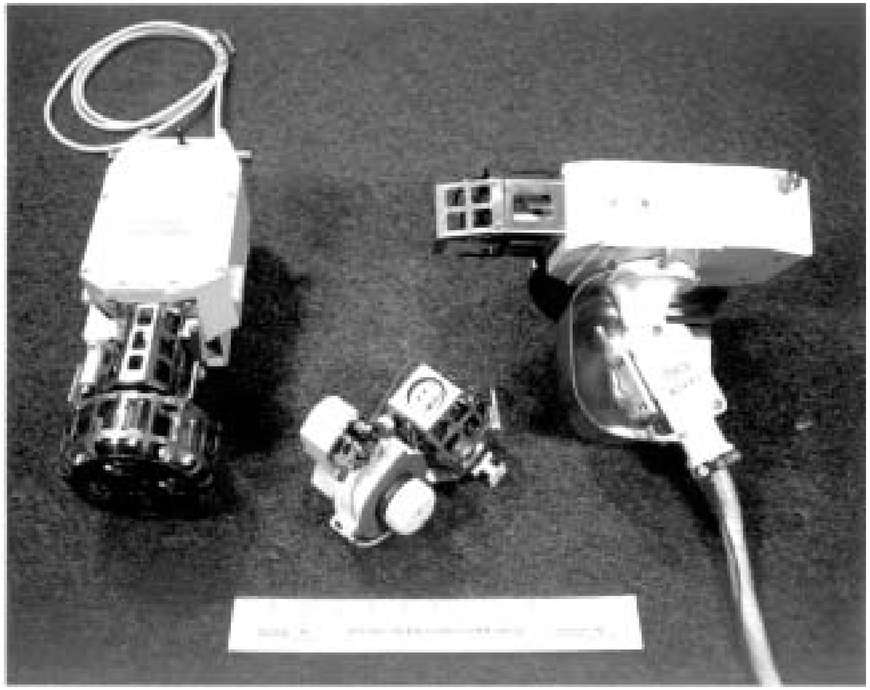
- First space welding experiment in 1969 using “Vulcan” evaluated 3 processes
- In 1970’s research concentrated on hand held electron beam tool, VHT
- VHT demonstrated in 1984 on Salyut-7 by S. Savitskaya and V. Dzhanibekov
- In 1986 VHT used on 3D structural mockups, also on Salyut-7
- In addition to NASA, working with DARA on proposed MIR demonstration

EXISTING CAPABILITIES

Universal Hand Tool (UHT)

Paton Welding Institute

- Power capacity
  - 1 kWatt at 8 kVolts
- Reconfigurable for multiple processes
  - Welding with and without filler metal (1 - 2 mm)
  - Brazing
  - Cutting (0.5 - 1 mm)
  - Vapor Deposition Coating



CURRENT STATE OF THE ART

- In-Space welding is feasible in the space environment of microgravity and vacuum
- Most experience is with electron beam welding
- The Ukrainian Universal Weld System is the only space qualified welding equipment currently available
    - Arc welding system developed but not flight qualified through Small Business Innovative Research Program
- In-space joining has been limited to bead-on-plate demonstrations
- No prior development of in-space joint preparation or post weld nondestructive inspection

OBJECTIVES of ISWE

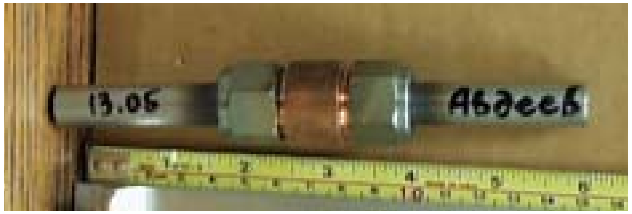
- To evaluate the UHT performance as a repair tool for International Space Station unplanned maintenance
  - Impact damage to modules
  - Fluid line leakage
  - Hardware removal
  - Vapor Deposition Coating
- To develop methods for working in the space environment
  - Several different joint configurations, materials, product forms
- To address hazards associated with Extravehicular (EVA) welding operations

REPRESENTATIVE SAMPLES

2219 Al Repair Patch Sample
U.S. Module

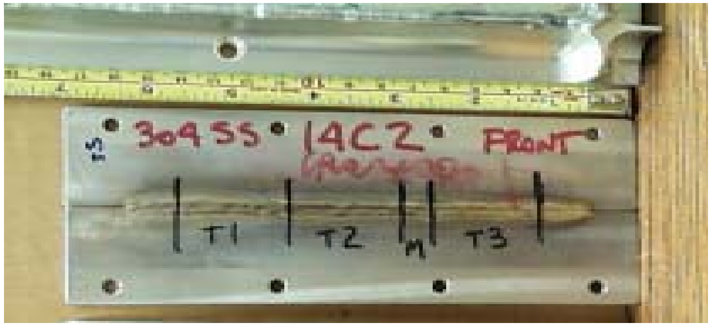
5456 Al Repair Patch Sample
Russian Module

REPRESENTATIVE SAMPLES CONT.



Tube braze sample

Tube pin hole samples



Square butt weld sheet sample

Lap fillet weld sheet sample

REPRESENTATIVE SAMPLES CONT.

Al cutting sample

Typical glass substrate for coating

EXPERIMENT DESIGN DRIVERS

- Science requirements
  Limits on number of samples
  Lighting, data acquisition, vacuum

- Space environment
  Microgravity, vacuum, contamination sources
  Ambient lighting, space suit restrictions

- Shuttle Payload Safety Requirements

- Crew training
  Availability, skill level

SHUTTLE PAYLOAD SAFETY REQUIREMENTS

- In compliance with NSTS 1700.7B for payloads
- In compliance with NSTS 07700, Vol XIV, App. 7 for Extravehicular Activities
- 5 General Hazards Identified
    - Electrical shock during EVA
    - Exposure or orbiter, crew, or other payloads to EMI
    - Structural failure
    - Safety critical mechanism failure
    - Standard hazards

SHUTTLE PAYLOAD SAFETY REQUIREMENTS CONT.

- 9 Payload unique Hazards Identified

  - Exposure of crew, orbiter, payloads to electron beam
  - Touch temperature extremes during EVA
  - Crew exposure to X-ray radiation
  - Release of molten metal and sparks
  - Crew exposure to intense visible light
  - Contingency return and rapid safing
  - Glass fragments in payload bay
  - Hazardous particulate in habitable atmosphere
  - Deposition of vaporized metal during welding

TECHNOLOGY DEVELOPMENT NEEDS

- Consider solid state joining
  - PRO – Eliminates safety issues associated with molten metal, vapor deposition, sparks
  - CON – May not be feasible for all repair scenarios

- Consider automatic welding for future efforts
  - PRO - Eliminates safety issues associated with human involvement and eliminates potential manifest restrictions
  - CON - Flexible “robotic” system not currently available (space qualified) and expensive to develop

- Weld porosity is a potential issue
  - Ground-processed aluminum samples with porosity
  - Similar results in Japanese microgravity research

TECHNOLOGY DEVELOPMENT NEEDS

- Consider IVA in-space welding demonstration first
  Eliminates space environment restrictions
  More hazard control

- Weld repair is viable technique - continue development for International Space Station unplanned maintenance

- Ancillary metals processing functions also need development for space operations such as
    - Joint preparation
    - Cleaning
    - Post-weld Nondestructive Inspection